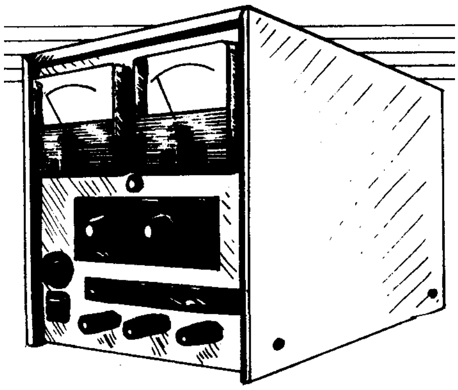
VARIABLE BENCH POWER SUPPLY



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Fully controllable from 0 to 24V, up to 2.5A output. Current limit control allows maximum output current to be set anywhere between zero and maximum.

THE power supply to be described here was designed to be capable of a wide variety of jobs. Its high output voltage of 0 to 25V and output current capability of 2.5A are far better than the more usual bench power supplied with their 12V and 1A ratings.

Output voltage is fully variable right down to zero (unlike a lot of i.c. regulators which stop at 1.5V) and a "Current Limit" control allows the maximum output current to be set anywhere between zero and maximum. The current limit feature has two particular uses. One is to protect circuitry under test from being damaged due to faulty construction – a real delight for electronics experimenters. The other use is in the constant current charging of NiCad batteries.

Its uses in the school science lab are too numerous to list in full, but such uses as electrolysis, electroplating, polystyrene cutting, and the like come to mind as well as the more obvious uses for driving model motors, computer interfaces and robots. Two large meters continuously display Voltage and Current leaving the user in absolutely no doubt about what is being provided.

Ripple and noise in the output are at a very low level and the output voltage change in response to load current changes and fluctuating mains voltage is very small. A supply of this type can never be cheap, the cost of transformer, case, heatsink and above all the meters soon add up, but the amount of use that such a project gets justifies the initial cost and the two meters are very worthwhile features. This is a project that will be used almost every day and will soon become indispensable.

CIRCUIT CONSIDERATIONS

A number of options are available when designing a supply of this type. Variable voltage i.c. regulators are available but all seem to have some disadvantages. The circuit finally chosen uses a simple high power device to handle the output, controlled by a low power integrator circuit which does all the "intelligent" work.

A power MOSFET was chosen as the output device because they are rugged, that is, able to withstand voltage and current surges, and also because the insulated gate requires negligible drive current. This second feature is very useful because it enables a simple small-signal transistor to be used as the output driver.

To understand how the circuit works the various sections of it are shown separately in Fig. la to Fig. ld. The final complete circuit diagram for the Variable Bench Power Supply is shown in Fig. 2.

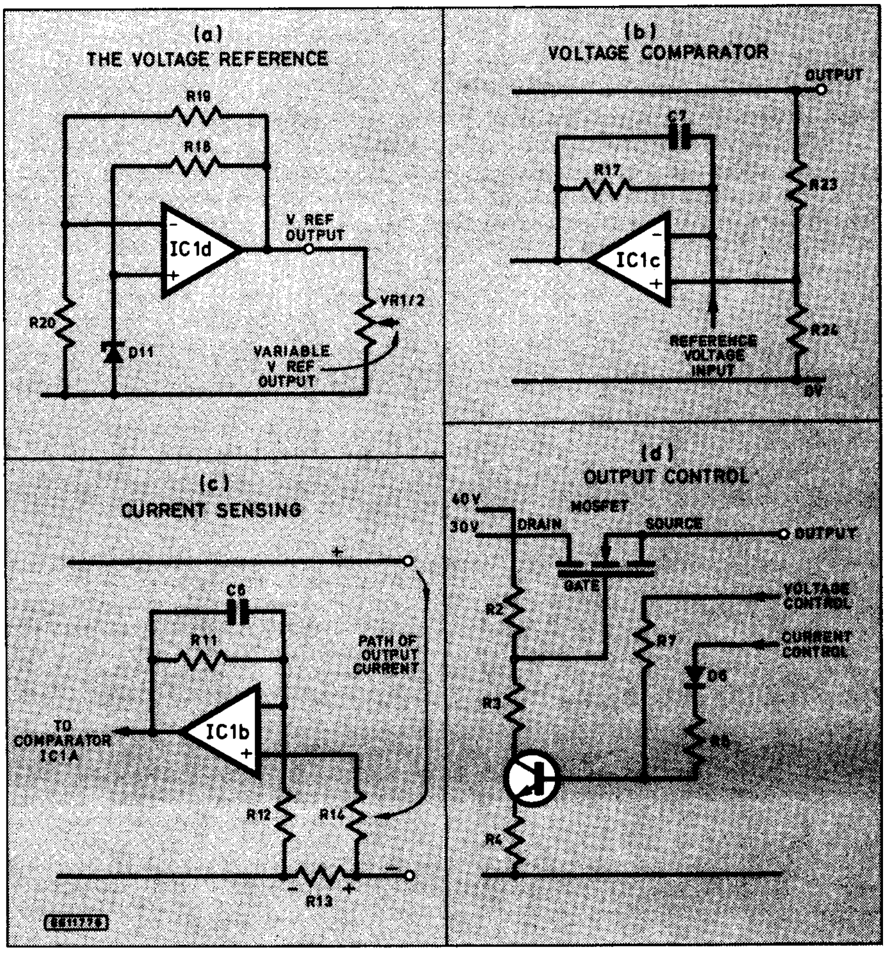
REFERENCE VOLTAGE

The first thing that a power supply control circuit needs is some sort of "reference voltage". This is used to set the output voltage and needs to be stable and noise-free if the power supply output is to be clean.

Fig. la shows the voltage reference section of the circuit. Zener diode D11 is the primary reference source. A 5.6 volt Zener diode has been chosen because these have the lowest variation with temperature (temperature co-efficient) of all Zener values. Above and below this voltage the stability is not so good.

To get the best performance from a Zener diode it is best to drive it with a constant current. This is achieved very neatly by ICld and the associated resistors.

Fig. 1. The various sections of the Variable Bench Power Supply Circuit



Upon switch-on there is a low voltage across D11 which therefore does not conduct and acts like a very high value resistor. The pairs of components resistor R18, diode D11 and resistors R19, R20 are two potential dividers driven from the output of ICId.

At low voltages, with D11 not conducting more of the output voltage from ICId is connected to the non-inverting input (+) than to the inverting input (–). The net effect is overall positive feedback that pushes up the output of IC 1 d . At a certain point the voltage across diode D11 will reach 5.6V and it will begin to conduct. The non-inverting input of ICId is now held at 5.6V.

The output of IC Id still continues to rise until the inverting input which is fed from the output via resistors R19 and R20 also reaches 5.6V. When this occurs the circuit stabilises with the output voltage set by the Zener diode voltage and the ratio R19 + R20/R20. The values chosen here give an output of 10 volts from IC 1d. The current through D11 is fixed by the output which is at 10V and the Zener diode at 5.6V which leaves 4.4V across resistor R18 giving a current of 4.4mA.

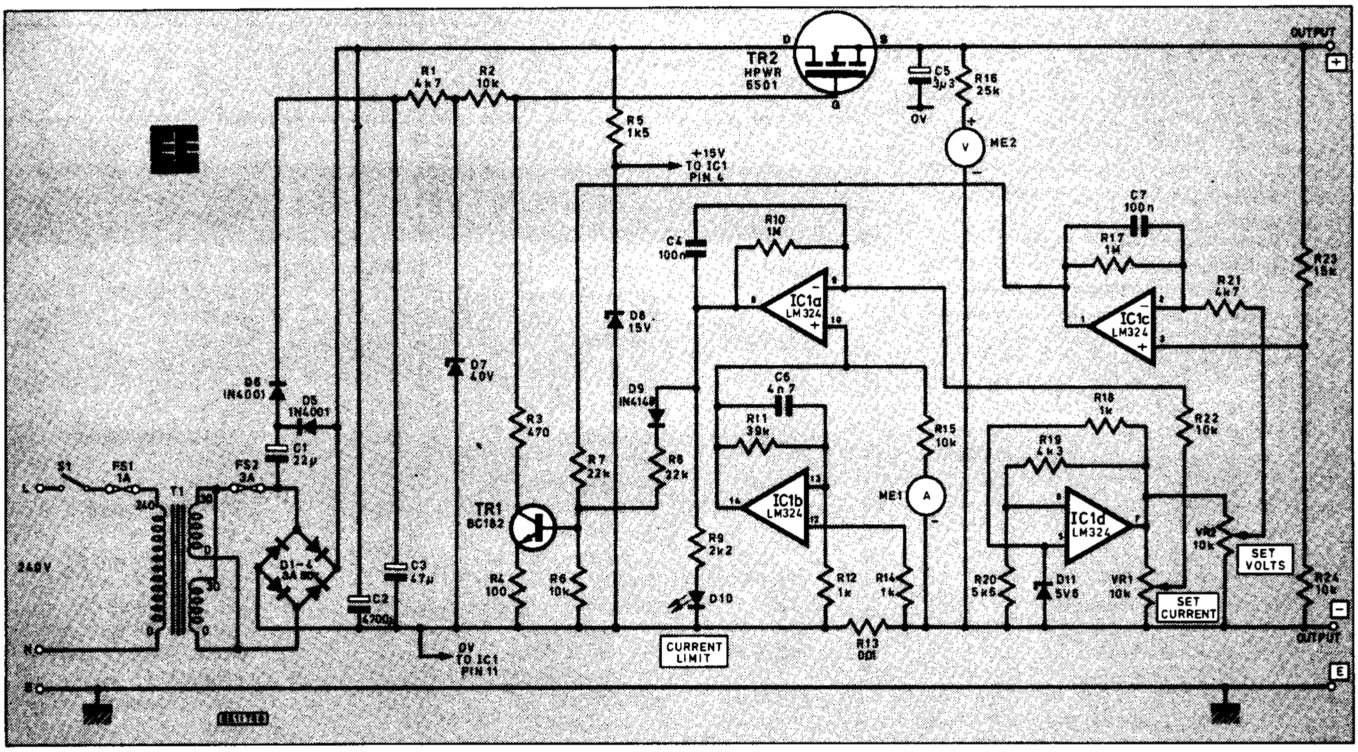


Fig. 2. Complete circuit diagram for the Variable Bench Power Supply. The operation of this circuit is best understood by referring to Fig. 1.

The important thing is that all of these values are set up by diode D11. The power supply input and output voltages have no effect whatsoever.

The stable reference voltage from ICld is fed to the two control potentiometers VR1 and VR2. The output from each of these is a voltage which varies between zero and 10V as the control is rotated clockwise.

VOLTAGE

This voltage is used by the next stage of the circuit, the "voltage comparator", which is shown in Fig. 1b. A proportion of the power supply output voltage is tapped off by resistors R23 and R24 and fed to one input of IClc. The other input of IClc is fed from the slider (or wiper contact) of potentiometer VR2. The values of resistors R23 and R24 are selected so that at 25V output the voltage at their junction is 10V.

IC lc is connected as a high gain amplifier that amplifies the difference between its two (inverting, and non-inverting) inputs. If the tapped off voltage from the output exceeds the voltage from VR2 slider, the output of IClc is driven positive. This rising voltage acts on the output control circuit (Fig. 1d) in such a way that the output voltage is reduced.

If the output falls so that the voltage tapped off from the output becomes less than that from VR2 slider, the opposite things happen and the power supply voltage increases. In this way the circuit stabilises itself so that the two inputs of IClc are kept equal. Any tendency for the output voltage to vary due to loading or mains voltage changes is instantly corrected as IC lc re-balances its inputs and sends a signal to the output control circuits.

CURRENT SENSING

Output current control is carried out by IC lb, the "current sensing" circuit. Resistor R13 in Fig. lc is connected in series with the power supply negative line. All of the output current flows through this resistor producing a voltage drop across it. This is used by IClb, via resistors R12 and R14, and amplified to produce a voltage which varies from 0 to 10V as the current increases from zero to 1.5A

This voltage is used to drive the output current meter which is connected via R15 to give full scale deflection (f.s.d.) at 10V. The voltage is also fed to a second voltage comparator circuit (ICla) and compared with the voltage from the slider of the Set Current control VR1.

Operation of this circuit is the same for current as Fig. lb is for voltage. Its output is fed to the output control circuit via diode D9 and resistor R8, and also to the current limit indicator l.e.d. D10.

Whenever the output current attempts to exceed the value set by VR1, the output of ICla rises, diode D10 is lit, and the output control circuit operates to reduce the drive to transistor TR2 and hold the current steady. Varying VR1 from zero to maximum allows the current limit to be set anywhere between zero and a maximum of 2.5A.

OUTPUT CONTROL

The control of the output of the power supply is dealt with by the power MOSFET device transistor TR2 which is driven by transistor TR1. This particular type of MOSFET is an N -CHANNEL ENHANCEMENT type. This means that its gate (g) terminal must be at a voltage more positive than its source (s) in order for it to conduct.

For this particular device the minimum voltage required to start conduction is 3V, and up to 9V are required to give an output current of 3A. At maximum output, the voltage of transistor TR2 must be able to rise to 25 + 9 volts. This is provided, via resistor R2, from a 40V Zener regulated supply derived from the transformer by a voltage doubling circuit.

It is necessary to use a voltage doubler because the rectified transformer output voltage across the mains smoothing capacitor C2 is only 30V at full load. Driver transistor TR1 controls the gate voltage of TR2 via R3.

As the base of the TR1 is made positive it is turned on and the gate voltage of TR2 is pulled down lowering the output voltage. Signals from the voltage and current sensing circuits are both connected to TR1 base and so control the output.

Diode D9 is fitted in the current control circuit so that there is no interaction between this and the voltage control as long as the output current remains below the circuit limit setting. Once the circuit is in current limit mode D9 conducts and current control takes over from voltage control.

All the details of the circuit have already been explained individually. In Fig. 2 they are shown as a whole with a few additional (essential) components such as fuses, a mains transformer, smoothing capacitors, and voltage regulating Zener diodes.

Incoming mains to the transformer T1 passes via the power on/off switch and a IA fuse in a panel fuseholder. Most transformers nowadays are wound with two equal secondary windings which can be series or parallel connected to give a choice of outputs.

Transformers with two 15V or two 30V secondaries may be used. In the first case connected in series and in the second connected in parallel.

From the transformer secondary the output passes via a 3A fuse to the bridge rectifier, Dl-D4, and on to smoothing capacitor C2. This is the main supply which passes to the drain terminal (d) of TR2 and on to the output. Power to ICI is derived from this supply via resistor R5 and is regulated to 15V by means of Zener diode D8.

A high voltage supply is produced from the transformer by coupling an additional a.c. output from the secondary via capacitor which is rectified by diodes D5 and D6 and added to the main positive supply. The result is a voltage of almost 80V across capacitor C3 which is reduced to 40V by resistor R1 and Zener diode D7. Forty volt Zener diodes are not always easy to obtain so provision is made on the p.c.b. for two 20V Zener diodes in series. Output voltage is displayed by means of a 1mA panel meter connected as a voltmeter reading 0-25 volts with a series resistor R16.

CONSTRUCTION

Most of the components are mounted on a single printed circuit board. The component layout and full size printed circuit board foil master pattern is shown in Fig. 3.

The board is mounted by means of the two potentiometers VR1 and VR2 which are direct p.c.b. mounting types. Other potentiometers may be used and can be wired "off board" to suit other case layouts.

Before fitting any components to the board eleven Veropins should be pressed firmly into the positions shown for external connections and soldered. Begin component insertion by fitting the low profile components such as diodes and resistors, and a socket for ICI.

Take particular care with the diodes to identify each type and its polarity because they all look very similar. Transistor TR1 should be fitted with its flat surface as shown, and must NOT be one of the types with "L" suffix as these have a completely different pin-out.

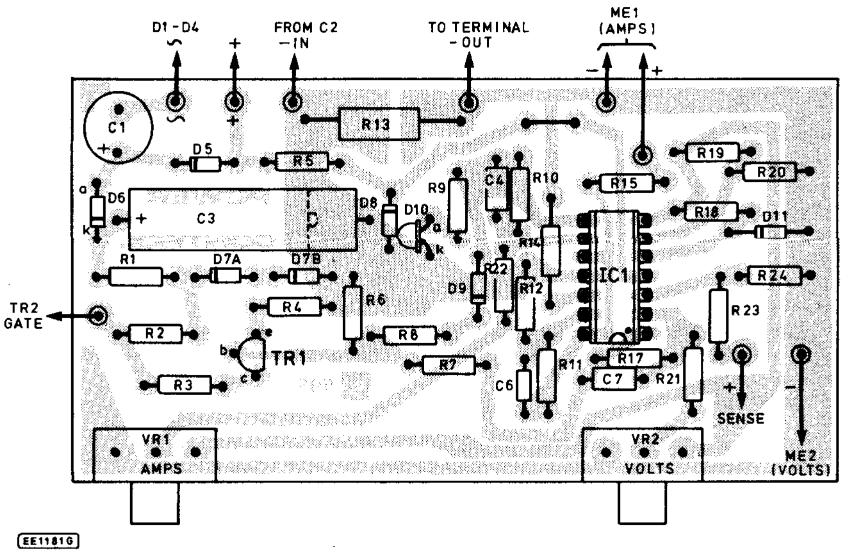
Capacitors C1 and C3 are polarised so must be fitted the right way round. Note that two holes are provided for C3 to enable different sized items to be accommodated. When the board assembly is complete, inspect the underside for solder bridges etc. Provided everything looks in order, the next stage is the wiring.

ASSEMBLY AND WIRING

A full wiring and assembly drawing is shown in Fig. 4. Fig. 5 shows details of the insulation of TR2 from its heatsink and the mounting of a toroidal type transformer is shown in Fig. 6.

Take great care with the mains wiring to fully insulate *every* joint with a good length of sleeving and to make all connections mechanically good before soldering them. A mains cable entry clamp is used to secure the cable firmly and prevent it from being pushed, twisted or pulled from the case. An additional "p" clip near to the front of the case is also needed to keep the cable in position. The mains Earth connection is made to a solder tag on the bottom of the case and brought out to a terminal on the front panel.

The rest of the wiring is quite straightforward but the wiring between the transformer, rectifier, capacitor C2, TR2, the board and the output terminals must be done



COMPONENTS

Resistors

R 1	4k7 Y2 W carbon film
R2, R6, R22	10k (3 off)
R3	470
R4	100
R5	1 k5
R7, R8	22k (2 off)
R9	2k2
R 10, R 17	1M 0.25W 1% metal film (2 off)
All	39k 0.25W 1 % metal film
R12, R14, R18	1k(3off)
R13 0R1	2.5W wirewound
R15, R24	10k 0.25W 1 % metal film (2 off)
R16	25k 0.25W 1 % metal film (made from 10k + 15k in series)
R 19	4k3 0.25W 1 % metal film
R20	5k6 0.25W 1 % metal film
R21	4k7
R23	15k 0.25W 1 % metal film

All 0.25W 5% carbon film, except where stated

Potentiometers

VR1, VR2	10k lin. (2 off)

Capacitors

C1	22p radial elec. 63V
C2	2,500p + 2,500p tag-ended elec. 63V
C3	47p axial elec. 100V
C4, C7	100n min. polyester (0.3in pitch) 100V
C5	3.3u axial elec 40V
C6	4n7 Mylar or polyester 63V

Semiconductors

D1-D4	3A 50V bridge rectifier
D5, D6	1N4001
D7	40V 500mW Zener diode (or 2 x 20V in series)
D8	15V 500mW Zener diode
D9	1 N4148
D10	3mm low current red l.e.d.
D11	5V6 500mW Zener diode
TR1	BC182 npn silicon
TR2	HPWR 6501 MOSFET (N-channel)
IC1	LM324 Quad op. amp.

MAGENTA KIT 769

Miscellaneous

Si	s.p.s.t. miniature rocker switch
Ti	120V/A Toroidal mains transformer – primary 240V mains, sec. two 30V windings (see text)
ME1,ME2	1mA 65 ohm, moving coil panel meter (2 off)

Printed circuit board; heatsinks; insulating kit (T03); knobs (2 off); screw terminals, 1 red, 1 black, 1 green; capacitor clip; wire, mains and low voltage; fuse, primary 1A 1-1/4in with panel holder, secondary 3A 20mm with chassis holder; case; feet for case; nuts, screws, etc.

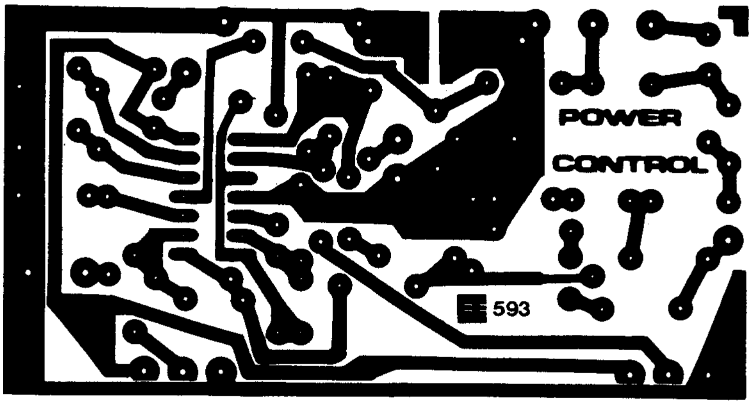


Fig. 3. Full size foil master pattern and component layout.

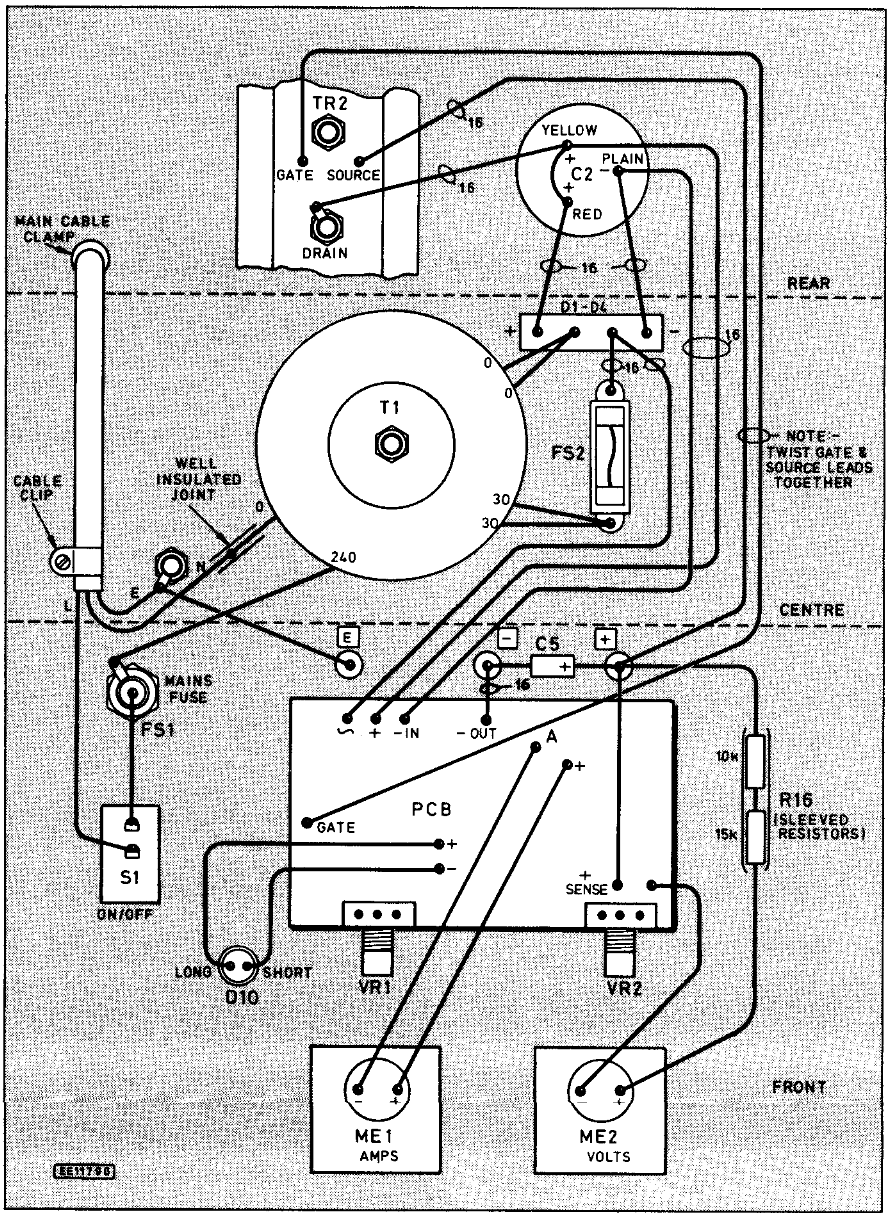


Fig. 4. Full wiring and assembly details to the circuit board, transformer and case mounted components. Heavy duty wires which carry the full output current are indicated by the number 16.

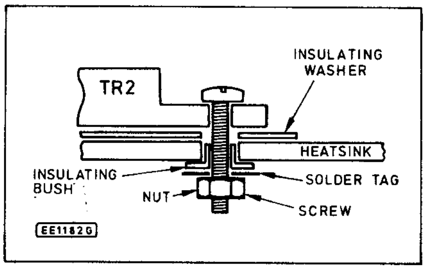


Fig. 5. Details of mounting the MOSFET device on the heatsink.

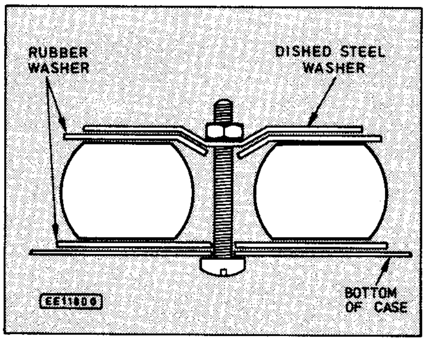


Fig. 6. Method of mounting the toroidal transformer in the case.

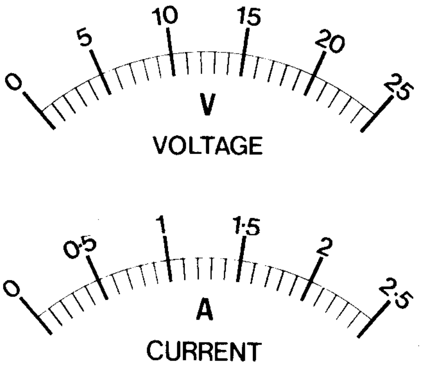


Fig. 7. Full size Voltage and Amps scales for the power supply

exactly as shown to keep ripple currents to a minimum.

Some wires carry the full output current, and so should be thicker than others. These wires have been marked with a circle and the number 16 to indicate that at least 16/0.2 wire should be used. All other connections may be made using 7/0.2 wire.

The leads to the gate and source of TR2 should be twisted together. When mounting TR2 to the heatsink it is necessary to use thermal compound on *both* sides of the insulating washer to ensure good heat transfer.

TESTING

Commence testing by first checking and double checking everything; make sure the mains wiring is correctly insulated and switch on. If the fuse does not blow it is possible that everything is working correctly.

Set VR1 halfway, vary VR2 and see if the voltage reading on the output meter is varying. If it is, well done. If not, the next step is to check a few voltages around the circuit.

There should be 40V across C2 and 80V across C3. If these are not correct check the voltage across diode D4 which should be 40V and across D8 which should be 15V. If any of these are low it is likely that they have been fitted the wrong way round, or that ICI is reversed. As these are standard power supply circuits it should be fairly simple to trace any faults here.

The next thing to check is the voltage across Zener diode D11 which should be 5.6V and then the output of ICld (pin 7) which should be b y. If things are still not right then it could be TR1 which is at fault.

Check the base voltage and collector voltages of transistor TR1. If the base voltage is less than 0.6V the collector voltage should be high. TR2 is unlikely to be at fault, but if its drain and gate are at high voltages and the source is very low or zero it is faulty.

After these tests it is really rather more of a detective job to find faults, but remember that 99 out of 100 faults are due to bad soldering or wiring.

OPERATION

Once the Voltage control is working correctly, connect a load (100 ohm resistor) across the output and check that the current reading increases as the voltage increases. At 25V a 100 ohm resistor should take 250mA.

Now reduce the current limit setting so that the current reading falls and note that the voltage reading also falls.The current limit l.e.d. should light at the point where the current just begins to reduce. Decrease the voltage setting and the circuit will resume voltage control as the l.e.d. goes out.

When testing a suspect (or newly built) circuit use the Voltage and Current limit controls to prevent excess power from being taken in the event of a fault. Start with both controls at zero and gradually increase them little by little until the expected circuit working current is reached.

If the controls are now advanced further and the current does not increase, then all is well. If the current continues to increase above the expected level then it is probably necessary to do some fault finding.

To charge NiCad batteries set the voltage to twice the total voltage of the batteries to be charged, and set the charge current using the current limit control. Note that you *must* remember to switch off after the correct time has expired to fully charge the batteries, especially when charging at higher rates. *Failure to do this can result in the battery being damaged and at worst exploding.*

In some circumstances the heatsink can get very hot. This is especially so when *a High* current is being delivered at *a Low* voltage. In this instance TR2 is carrying the high current and is dropping most of the voltage as well.

At 2A and 25V this can be so much as 50 watts. Just think how hot a 60 watt light bulb gets and you get some idea of the heat dissipation requirement. For moderate durations this sort of power can be tolerated, but prolonged use at this level is not recommended.

When *full* current and voltage are being used, the power transistor has just a few volts across it and so is perfectly happy, and at medium output levels power is divided between the load and the power transistor which only generates moderate heat.

If continuous use at high currents and low voltages is anticipated a larger heatsink would be a good idea. ❑